DOCKETED	
Docket Number:	19-SB-100
Project Title:	SB 100 Joint Agency Report: Charting a path to a 100% Clean Energy Future
TN #:	230840
Document Title:	Arne Olsen - Long-Run Resource Adequacy under Deep Decarbonization Pathways for California
Description:	Presentation by Arne Olsen, Energy and Environmental Economics, Inc. (E3)
Filer:	Harinder Kaur
Organization:	California Energy Commission
Submitter Role:	Commission Staff
Submission Date:	11/25/2019 10:29:20 AM
Docketed Date:	11/25/2019

Energy+Environmental Economics

Long-Run Resource Adequacy under Deep Decarbonization Pathways for California

SB100 Technologies & Scenarios Workshop

November 18, 2019

San Francisco, California

Arne Olson, Senior Partner

About This Study

- **California has established aggressive goals for economy-wide decarbonization and zero carbon electricity generation**
- **This study examines the question of what resources are needed to maintain resource adequacy in a deeply decarbonized system that is heavily dependent upon renewables + electric energy storage**
- **Two alternative scenarios are considered that each meet economy-wide goals of 80% reductions in GHG emissions below 1990 levels by 2050:**
  1. High Electrification
  2. High Biogas

CALPINE

This study was funded by Calpine Corp.

Disclaimer required by the California Public Utilities Commission

This report has been prepared by E3 for the Calpine Corporation. This report is separate from and unrelated to any work E3 is doing for the California Public Utilities Commission. While E3 provided technical support to Calpine in preparation of this report, E3 does not endorse any specific policy or regulatory actions as a result of this analysis.

The study uses three E3 models as the basis for analysis: California-wide PATHWAYS and RESOLVE models developed under California Energy Commission contract number EPC-14-069 and a California-wide version of E3's RECAP model developed for this project. Versions of these models have previously been used by E3 for projects completed on behalf of the California Energy Commission, the California Public Utilities Commission, and the California Air Resources Board. These California state agencies did not participate in the project and do not endorse the conclusions presented in this report.

The RESOLVE model used for this project is distinct from the RESOLVE model developed for the CPUC's 2017-2018 Integrated Resource Planning proceeding (R.16-02-007). A table summarizing the major differences in the RESOLVE model version used for this study and the version used in the CPUC's IRP proceeding can be found in the written report at:

https://www.ethree.com/wp-content/uploads/2019/06/E3_Long_Run_Resource_Adequacy_CA_Deep-Decarbonization_Final.pdf

Approach

This study was completed using three E3 models of the California electricity system

1. **California PATHWAYS model develops scenarios for meeting 2050 economy-wide decarbonization goals**
   - Electric Sector carbon budgets and electrification loads passed to RESOLVE

PATHWAYS
Economy-wide GHG Scenarios

2. **California-wide RESOLVE model developed least-cost resource portfolios to meet GHG targets**
   - Electricity resource portfolio passed to RECAP

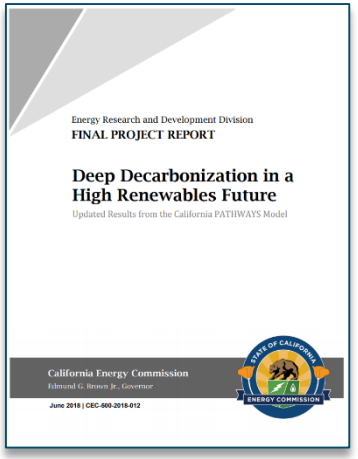
RESOLVE
Electricity Capacity Expansion

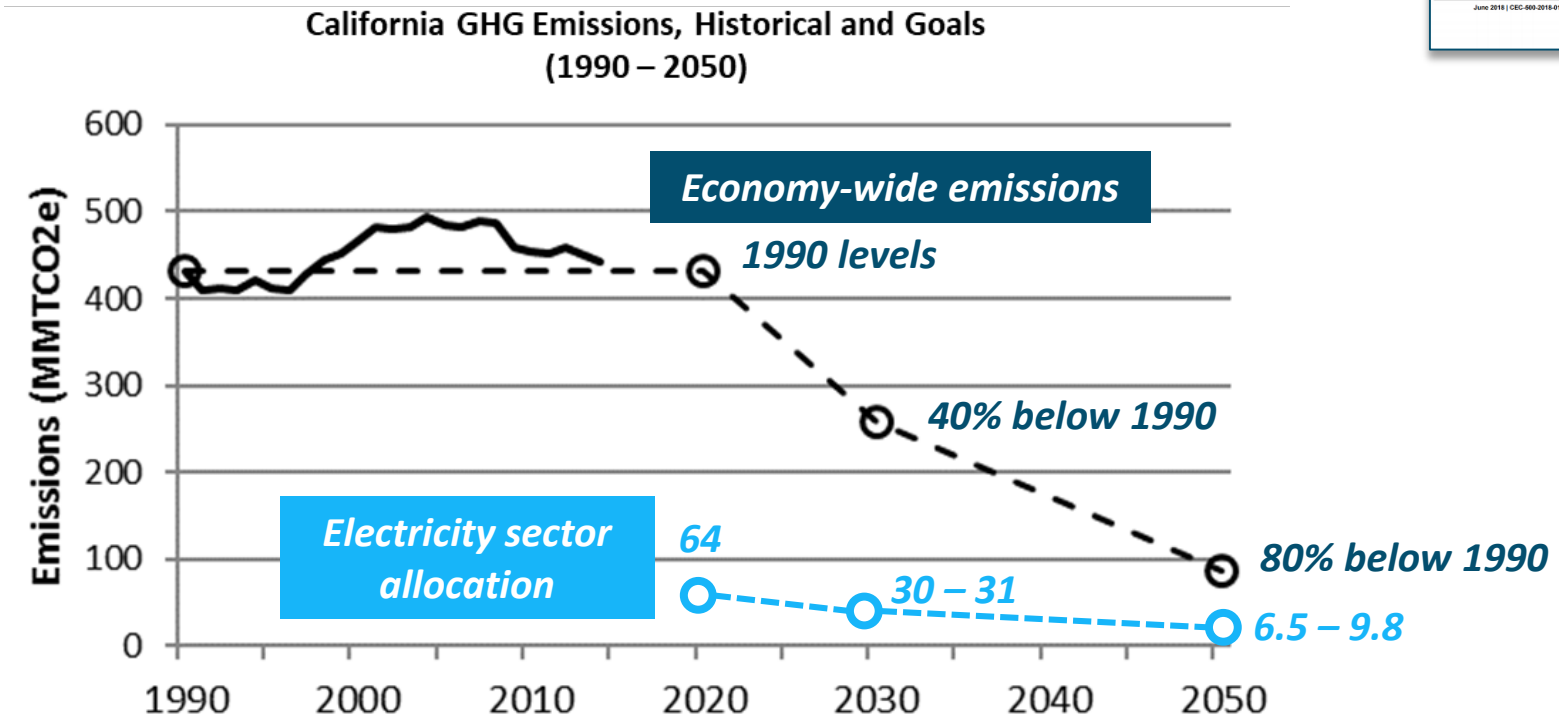
3. **California-wide RECAP model tests the reliability/adequacy of the resource portfolios**
   - Calculates Loss-of-Load Expectation

RECAP
Electricity Resource Sufficiency

E3's PATHWAYS model identifies technology adoption scenarios to meet economy-wide GHG goals

- Used in conjunction with E3's electric sector models to develop a robust picture of the role of electricity in meeting carbon goals
- Scenarios modeled here are based on CEC project *Deep Decarbonization in a High Renewables Future*



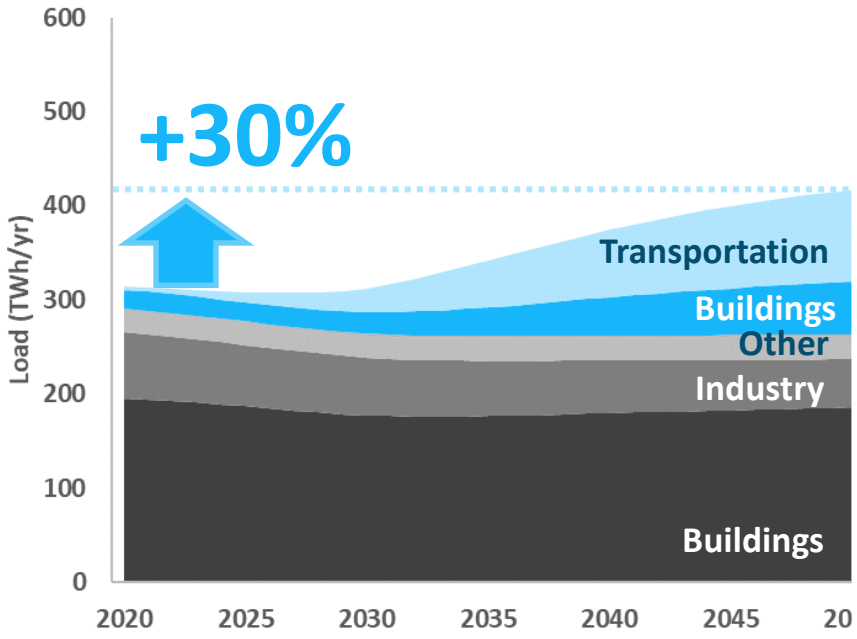


Two scenarios selected as bookends for future electricity demand

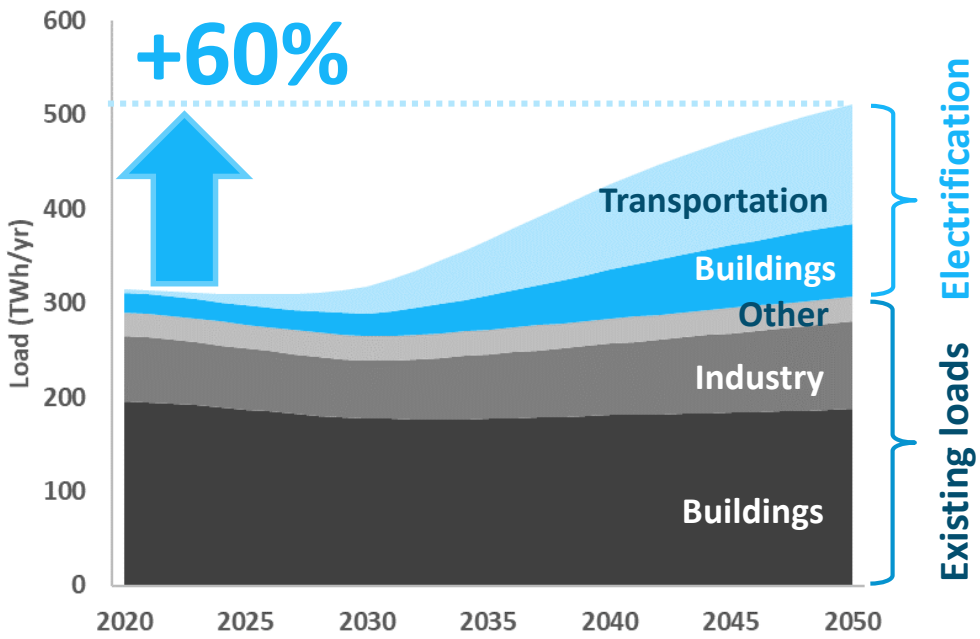
- Electrification of transportation and buildings aids in decarbonization of California economy
- The two scenarios represent bookend values for increased electric loads (30-60% relative to present)

	High Biogas		High Electrification	
	2020	2050	2020	2050
Annual Energy (TWh)	315	417	315	511
Peak Load (GW)	65	78	65	93

PATHWAYS High Biogas Scenario



PATHWAYS High Electrification Scenario

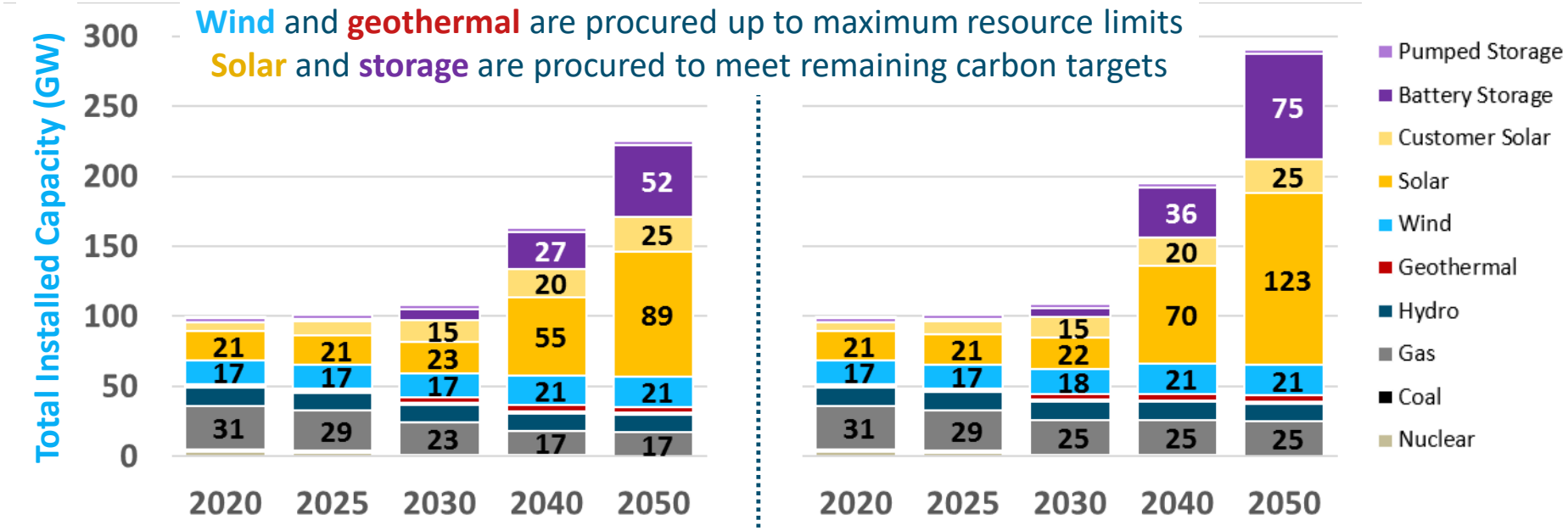


RESOLVE relies mostly on solar and storage to meet decarbonization goals

- **"100% Clean Energy" achieved by 2050 in both scenarios**
  - Assumes clean energy accounting is the same as today's RPS accounting (annual balancing period, current REC buckets, T&D losses excluded)
- **Very large quantities of wind, solar and energy storage selected**

High Biogas Scenario

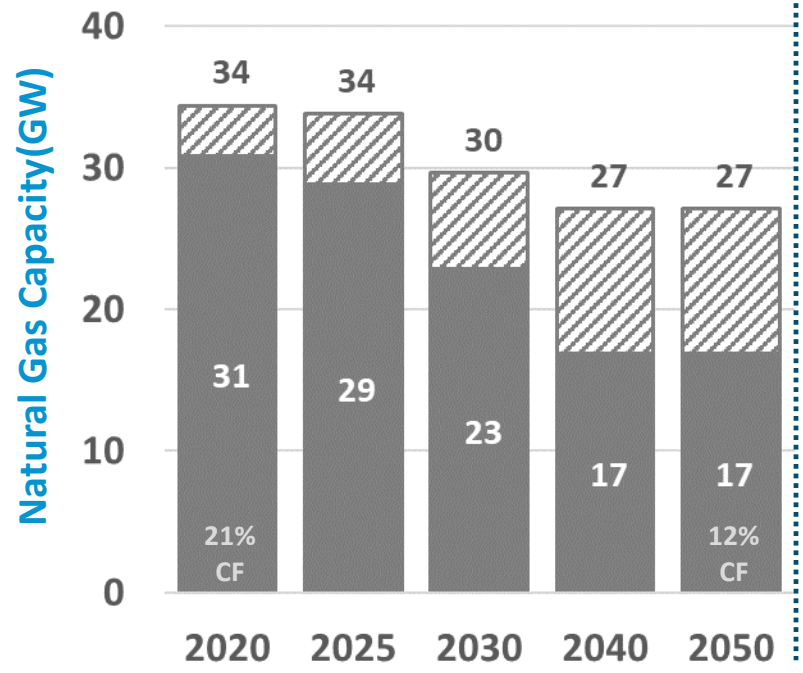
High Electrification Scenario



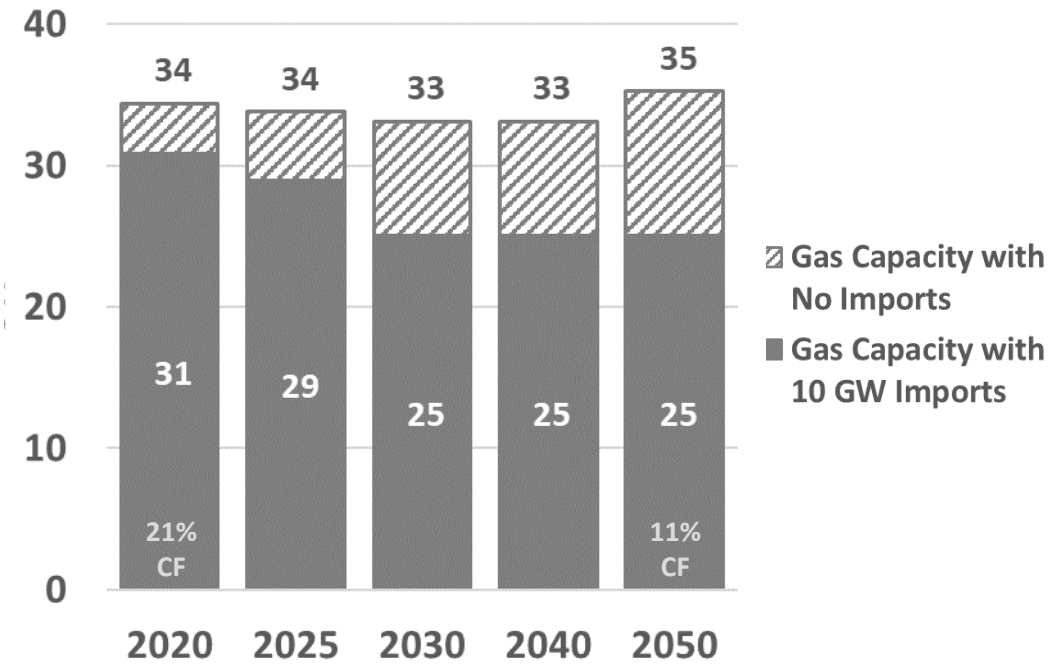
Given 6-10 MMT carbon budget, RESOLVE retains 17-35 GW of gas generation for resource adequacy

- Solar, storage, wind, and geothermal provide capacity value that allows for some retirement of gas generation
- Sustained periods of low renewable production, particularly during winter, limit substitutability of solar + storage for gas generation

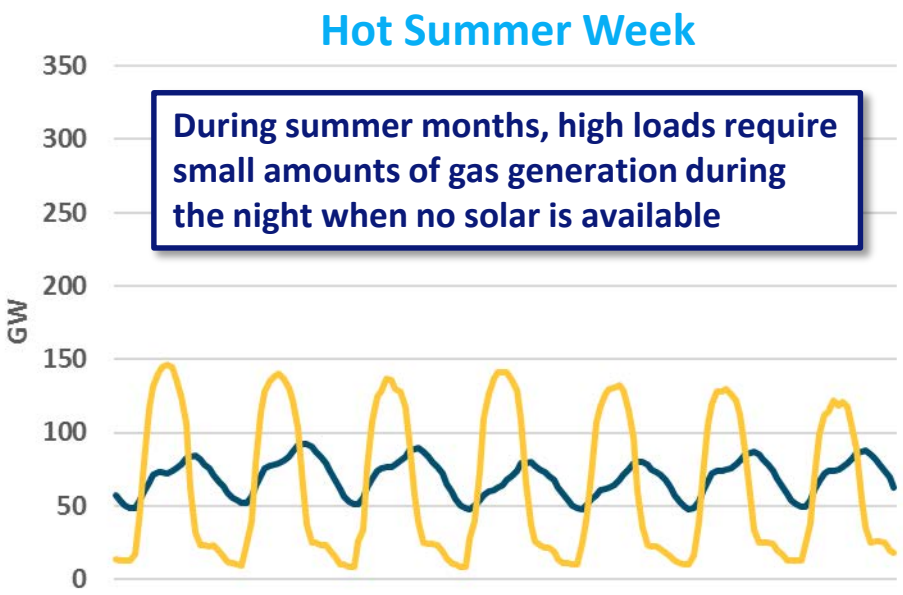
High Biogas Scenario

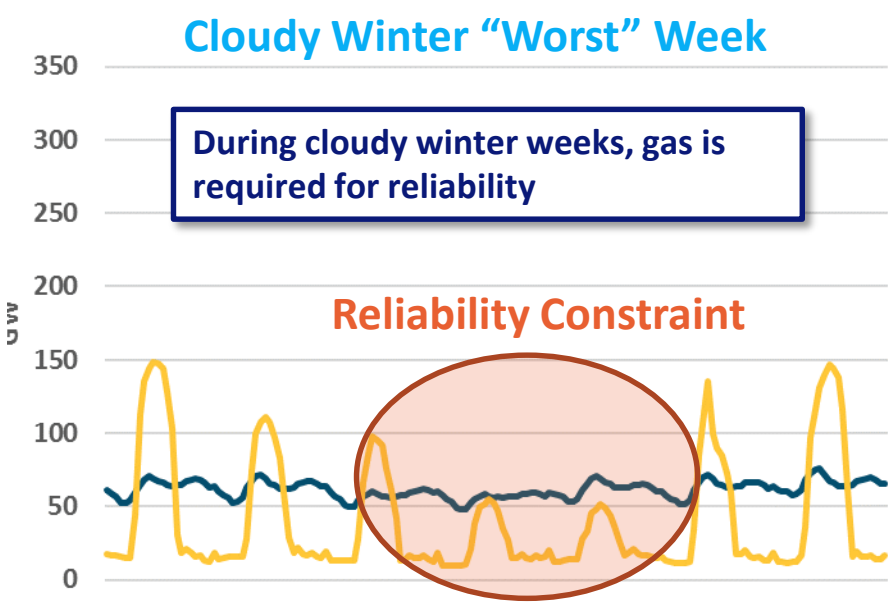


High Electrification Scenario



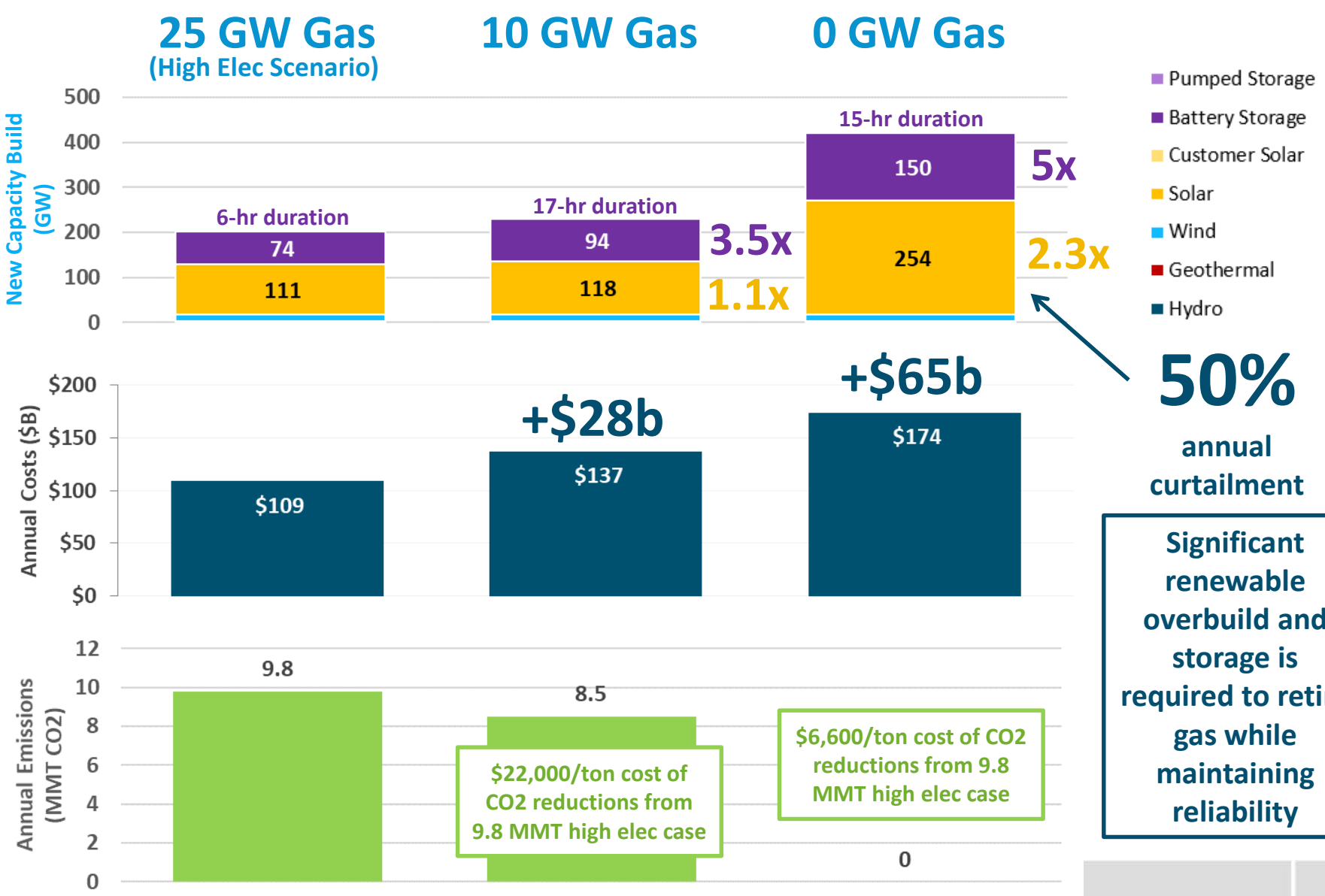
Cold, dark week in January becomes the main reliability constraint





- **"Firm capacity" is needed to maintain reliability during multi-day periods of low renewable production**
  - Resource that can start up when needed and produce energy over multiple days

Forced gas retirement is not effective at reducing carbon emissions



50%

annual curtailment

Significant renewable overbuild and storage is required to retire gas while maintaining reliability

Key Findings

1) **A least-cost plan for achieving an economy-wide GHG reduction goal of 80% below 1990 levels by 2050 requires 90-95% reduction in the electric sector**
   - Achieving economy-wide goals does not require complete decarbonization of electricity supply
2) **Some form of firm generation capacity is needed to ensure reliable electric load service on a deeply decarbonized electricity system**
   - Wind, solar, storage and demand response reduce the need for firm capacity but are not a perfect substitute
   - 17-35 GW of gas generation retained in the absence of a firm, zero-carbon resource
   - Candidate zero-carbon resources (not examined in this study) are fossil generation with CCS, nuclear, very long duration storage, zero-carbon gas
3) **It would be extremely costly and impractical to replace all natural gas generation capacity with wind, solar and storage**
4) **The findings are robust to key sensitivity drivers**
   - 23 GW of gas generation retained even under 3 MMT scenario

Energy+Environmental Economics

Thank you!

Energy and Environmental Economics, Inc. (E3)
44 Montgomery Street, Suite 1500
San Francisco, California 94104
Tel 415-391-5100
Web http://www.ethree.com

Arne Olson, Senior Partner (arne@ethree.com)